Current limitations in the use of bat detectors to assess the impact of logging — a pilot study in south-east Queensland

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ABSTRACT

A pilot study, using remotely deployed ultrasonic bat detectors, was undertaken in the Conondale Ranges as part of a research programme to assess the impacts of wet sclerophyll logging on native wildlife. The remote system was of the voice activated type and tested because of its costs relative to other systems. The remote detection technique was inefficient as a means for identifying all potential species that occur in the area, because of slow response by the equipment to switch on in response to bat calls, problems with high noise to signal ratio and the behaviour of some species relative to the remote equipment. Only eight species were recorded out of a potential eighteen species that occur in the Conondale Ranges. The highest diversity and activity measures were recorded in the intermediate site, last logged in 1961, and the lowest in the regrowth site. These preliminary results are not conclusive because of small sample size and difficulties with the methodology.

Key words: Bat detectors, Forest bats, Logging impact, Remote sampling, Conondale Ranges.

INTRODUCTION

The advent of new techniques for studying bats (e.g., ultrasonic detection, harp trapping, light tagging) is revolutionizing our ability to obtain information on these once overlooked forest denizens. Microchiropterans form a significant component of the forest fauna and should receive considerate attention when undertaking fauna surveys, research or monitoring studies (Law 1996). Harp trapping has had wide acceptance as an efficient technique, but other methods, such as the remote use of ultrasonic detectors, are still undergoing basic field testing. This paper describes the difficulties experienced during field trials with remotely deployed systems. Few researchers have undertaken investigations of logging impacts on bat assemblages (e.g., West 1992; Kutt 1995; Brown *et al.* 1997), yet the need for such information is necessary to achieve the ecologically sustainable forestry objectives required by the National Forest Policy (Anon. 1982). Law (1996) reviewed the literature concerning the effects of forestry on bats, largely from studies in southern Australia. These studies yielded conflicting results, which hinder a conclusive interpretation; but current evidence suggests a negative effect on bat populations when few hollow trees are left and the complexity of the forest is reduced (e.g., Brown *et al.* 1997). There is a paucity of detailed information available, particularly on the time required for foraging habitat to recover and which species are most affected by timber harvesting.

The Conondale Ranges (100 kilometres to the north of Brisbane) has been logged for over 100 years with Red Cedar *Toona ciliata* removed late last century. Recent surveys have revealed eighteen species of micro-chiroptera occur in the region (Kehl and Corben, unpubl. data; M. Schulz and L. Hall, pers. comm.). There has been no previous attempts to assess habitat preference, the effects of different harvesting and silvicultural treatments or how bats utilize forests post-harvesting. The principal aim of this study was to systematically test a method for achieving this. We further discuss the method chosen, its achievements and failures and its ability to answer the question of whether differences occur in bat assemblages and activity across differently aged, harvested forest stands.

STUDY SITE

Site description

The Conondale Ranges separate the catchments of the Brisbane and Mary Rivers between the Jimna and Blackall Ranges (Fig. 1). The predominant vegetation is rainforest, tall wet sclerophyll forest with an understorey of rainforest in mid-slopes and ridges, dry sclerophyll forest on the drier ridges, and approximately 50-year-old, and younger, hoop pine plantation.

Study sites within the Conondale Ranges were selected on the basis of the Department of Primary Industries (DPI) Forestry's computer based Area Information System (AIS), which contains information such as area of logging units, the year last logged and species composition. All sites chosen occurred in wet sclerophyll forest; other criteria for site

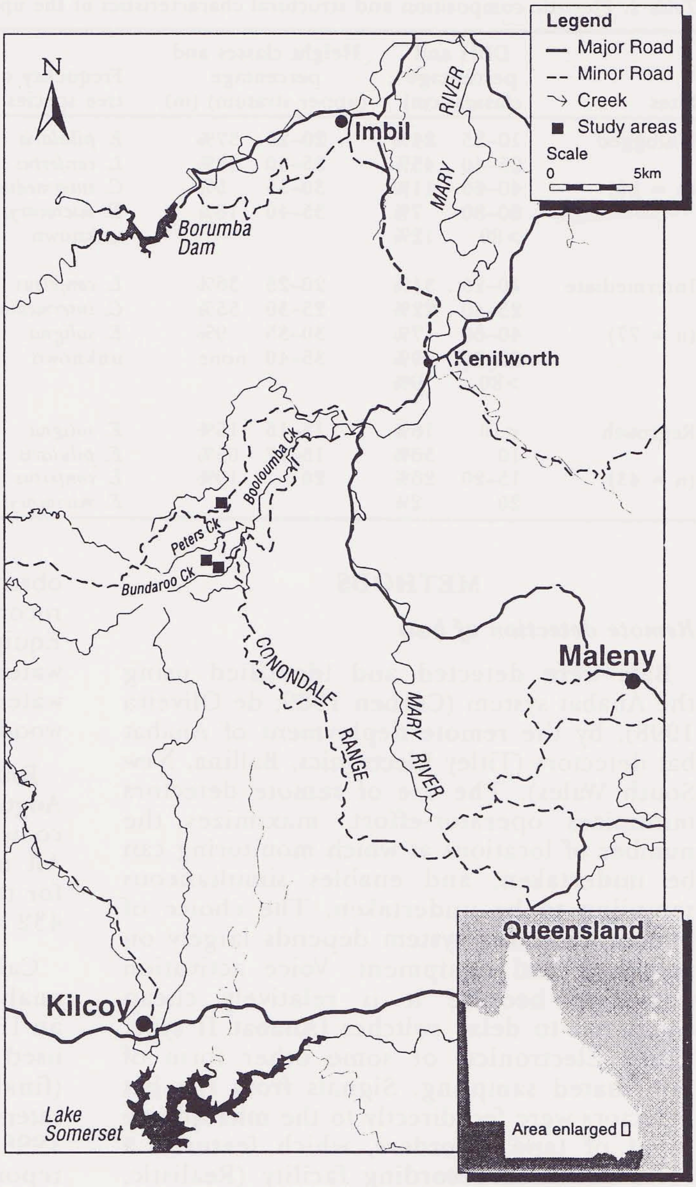

Figure 1. The Conondale Ranges showing the location of study sites. Inset shows the location of the Conondale Ranges in southeastern Queensland.

selection were: aspect (north), relief feature (ridge) and similar dominant tree species prior to timber harvesting (mainly Brush Box *Lophostemon confertus* and Blackbutt *Eucalyptus pilularis*, see below). Because of the constraints of these criteria, only three sites were available. These were: an unlogged site that was part of an unlogged catchment area; a site last logged in 1984 (referred to hereafter as regrowth); and a site last logged in 1961 (referred to hereafter as intermediate). DPI Forestry practices selective harvesting according to codes of practice and harvesting guidelines that aim to minimize impacts of operations on the ecology of forests and to promote sustainability.

The vegetation was assessed at each site following McDonald *et al.* (1990): (1) frequency of dominant tree species in the upper and mid-canopy strata; (2) frequency of diameter at breast height (DBH); (3) height classes; (4) mean crown width; and (5) mean crown gap. Crown separation ratios (= mean crown gap/mean crown width) and percentage foliar cover were also calculated. Vegetation sampling at three sites within the intermediate and the unlogged sites was conducted along three zig-zag transects (as per McDonald *et al.* 1990), each quadrat was 100 metres × 10 metres, and was located 50 metres to each side of the places where the remote detection equipment was deployed. A different sampling procedure was opted for the regrowth site, because of its uniformity and structural distinctiveness from the other sites. Sampling within the regrowth site was limited to two 5 × 10 metre quadrats, selected at random. Characteristics of the vegetation in each site are summarized in Table 1.

Table 1. Floristic composition and structural characteristics of the upper vegetation stratum in each of the treatments.

Sites	DBH and percentage classes (cm)		Height classes and percentage (upper stratum) (m)		Frequency of tree species		Mean crown width/diam. (m)	Mean crown gap width (m)	Crown separation ratio (m)
Unlogged	10–25	24%	20–25	37%	*E. pilularis*	37			
	25–40	45%	25–30	42%	*L. confertus*	36			
(n = 80)	40–60	11%	30–35	5%	*C. intermedia*	11	9.23	−1.34	−0.14
	60–80	7%	35–40	16%	*E. microcorys*	5			
	>80	12%			unknown	10			
Intermediate	10–25	31%	20–25	36%	*L. confertus*	46			
	25–40	22%	25–30	55%	*C. intermedia*	13			
(n = 77)	40–60	17%	30–35	9%	*E. saligna*	6	8.63	−0.75	−0.09
	60–80	19%	35–40	none	unknown	34			
	>80	9%							
Regrowth	<10	16%	13–15	16%	*E. saligna*	93			
	10	56%	15–17	65%	*E. pilularis*	2			
(n = 43)	15–20	26%	20	19%	*L. confertus*	2	2	+0.5	+0.25
	20	2%			*E. microcorys*	2			

METHODS

Remote detection of bats

Bats were detected and identified using the Anabat system (Corben 1989; de Oliveira 1998), by the remote deployment of Anabat bat detectors (Titley Electronics, Ballina, New South Wales). The use of remote detectors minimizes operator-effort, maximizes the number of locations at which monitoring can be undertaken, and enables simultaneous sampling to be undertaken. The choice of remote detecting system depends largely on resources and equipment. Voice activation was used because it is relatively cheap compared to delay switches (Anabat II type, Titley Electronics) or some other form of punctuated sampling. Signals from the bat detectors were fed directly to the microphone input of tape recorders, which featured a voice activated recording facility (Realistic, Minisette-20, Cat. No. 14-1055B). This enabled automatic recording on to audio-cassettes of any signals picked up by the bat detector. The equipment was switched on before dusk, left running overnight and switched off after sunrise. During the night, each remote station was inspected after two to three hours of operation to ensure enough tape space remained for the night and the units were functioning. New alkaline batteries were used in the recorders every night, and every second night in the detectors, to avoid any tape flutter due to power fluctuation.

Nine sets of detectors and recorders (three in each age class, pseudo-replication) were deployed simultaneously. The stations were 60–300 metres apart in a straight line in two sites and in a semi-circle in the regrowth site. These stations were oriented along obvious natural flight paths (not roads or built tracks) within each site or away from obstructions, to increase the chance of recording bat passes, for testing purposes. Equipment was protected from rain by water-proof containers and mini-tents. The water-proof containers were supported by a wooden prop on an angle of 45°.

Four seasons between November 1994 and August 1995 were sampled; each was timed to coincide with the First Quarter or New Moon. All nine sites were sampled simultaneously for three consecutive nights, giving a total of 432 sampling hours per age class of forest.

Calls were analysed using zero-crossings analysis with Anabat dedicated software on an IBM computer (Corben 1989). Parameters used to identify species included: frequency (final, range and rate of change), pulse interval, shape and pulse duration (de Oliveira 1998). Species nomenclature throughout this report follows Strahan (1995). Recorded calls were stored in Anabat computer files and these are lodged in the DNR microchiropteran ultrasound database. Bat activity was recorded as the number of bat passes per age class. A bat pass was defined when processing the tapes, as a call audibly delimited by the sounds of the tape recorder being switched on and off. This procedure cannot prevent the same individual being scored more than once, but it decreases the chance of the same individual, emitting pulses separated by pauses, being scored more than once during one pass.

RESULTS

Site comparisons

The regrowth forest was structurally less diverse than either the intermediate or the unlogged forest sites (Table 1). The regrowth site was dominated by small, regrowth

E. saligna whereas the other sites contained a range of species in a diversity of size classes. Mean crown diameter was smallest at this site and the crowns did not overlap.

The unlogged site was more diverse in its upper stratum, but had less rainforest species in the mid-stratum than the intermediate site. While it also had the tallest and broadest trees, on average, both sites had most trees in the same height class of tree. The intermediate site had a larger percentage (45%) of the bigger DBH classes (40–60, 60–80 and >80) than the unlogged (30%) site. At the unlogged site 69% of trees were in the 10–25 and 25–40 DBH class, while only 53% of trees occurred within these classes in the intermediate site. The mean crown diameter and the extent to which crowns overlapped (represented by the crown separation ratio) were greater in the unlogged than the intermediate site (Table 1).

The remote detection of bats

The remote ultra-sonic surveillance technique used in this study recorded a possible eight species, with only sufficient information to positively identify four to species level. Those were the Eastern Horseshoe-Bat *Rhinolophus megaphyllus*, the Eastern Forest Bat *Vespadelus pumilus*, the White-striped Freetail Bat *Nyctinomus australis* and Gould's Wattled Bat *Chalinolobus gouldii*. The remaining calls were distinctive enough for the identification of three other genera, with each genus considered to be represented by only one species. These were *Scotorepens* sp. (Broad-nosed Bats), *Nyctophilus* sp. (Long-eared Bats) and *Mormopterus* sp. (Freetail Bats). Another species could not be identified and is referred to here as 40/50 because its calls had a distinctive frequency range (i.e., between 40 and 50 kHz). A number of calls showed characteristics that could not be ascribed to a single genus; these were classified into *Mormopterus* sp./*C. gouldii* and as *Miniopterus australis*/*V. pumilus* groups.

A total of 211 calls recorded during the study was very low for the 1 296 hours of recording (0.2 passes/hour). Of this total, only 22 calls (9.4 %) were not useful; this percentage is relatively low (de Oliveira, unpubl. data). The majority (60.5%) were identified to species level, while the remaining 30.1% could only be identified to either genus (15.5%) or to one of the unidentified groupings of bats (14.6%: the 40/50 bat, the *Mormopterus*/*C. gouldii* complex, or the *M. australis*/*V. pumilus* complex).

The most frequently recorded species was *R. megaphyllus* (111 calls), followed by *V. pumilus* (23 calls); and *Nyctophilus* sp. (16 calls). *R. megaphyllus* was also the most widespread and frequently recorded species, being detected at all but two remote stations in the regrowth site, and recorded on more than half of all sampling sessions in the unlogged and intermediate sites. The frequency of detection for each species is shown in Table 2.

Species richness and bat activity were highest in the intermediate site; 97 calls were recorded from eight species, while 85 calls from five species were recorded in the unlogged site and 29 calls from three species in the regrowth site.

It took all four seasons to record the total number of species found in the unlogged site, while all species were recorded by the third season in the intermediate and by the second season in the regrowth site. The highest bat activity was recorded in Spring (88 calls), followed by Summer (65), Autumn

Table 2. Bat species, activity levels (i.e., the number of bat passes) and species' frequency of detection (% of total detection) recorded at each site. Frequency of detection was calculated for each sampling point and averaged per treatment.

	Age classes		
	Unlogged	Intermediate	Regrowth
Bat species		No. of bat passes	
Rhinolophus megaphyllus	49 (53%)	58 (58%)	4 (8%)
Nyctinomus australis	2 (3%)	1 (3%)	3 (6%)
Mormopterus sp.	1 (3%)	2 (6%)	10 (14%)
Mormopterus sp./*C. gouldii*	0 (n/a)	4 (3%)	7 (14%)
Chalinolobus gouldii	0 (n/a)	1 (3%)	0 (n/a)
Vespadelus pumilus	14 (11%)	9 (11%)	0 (n/a)
Miniopterus australis/ *V. pumilus*	9 (11%)	9 (50%)	5 (11%)
Nyctophilus sp.	10 (14%)	6 (11%)	0 (n/a)
Scotorepens sp.	0 (n/a)	1 (3%)	0 (n/a)
(40/50)	0 (n/a)	6 (8%)	0 (n/a)
No. of species	5 or 6*	8 or 9*	3 or 5*
Sampling effort (hours)	432	432	432
Total activity (no. of passes)	85	97	29

*The number of species depends on interpretation of the complex groups.

(35) and Winter (23). Bat activity between sampling points of the unlogged and regrowth sites differed more strongly than the intermediate (Table 3).

Table 3. Bat activity (No. of passes) recorded at each sampling point (box), all detection sessions combined.

Age classes	Box 1	Box 2	Box 3
Unlogged	25	34	26
Intermediate	27	54	16
Regrowth	19	2	8

DISCUSSION

Design considerations

Three main constraints affected the choice of the experiment design (i.e., three sites, each of a different age class, with three recorders in each site). Firstly, adequate replicates of the three age classes were not available. Secondly, the low number of recorded calls within the forested sites was anticipated because higher bat activity was observed to occur along flyways such as vehicle tracks and creek lines in the study area on different occasions (M. C. de Oliveira, pers. obs.), and during this study. And thirdly, the frequency of equipment failure or malfunction was unknown, thus a conservative approach was preferable. Therefore, pseudo-replication was used to maximize the chances of recording bats inside the forested plots; and to reduce the chances of equipment failure, which may have affected the results.

Bat detection — methodological problems with the voice activation technique

Two features of the data presented in this paper are of interest:

1. the overall numbers of bat passes recorded per hour were low (0.2 passes per hour) compared with studies from southern states (e.g., Rhodes 1996, minimum of 1.5 to maximum of 6.9 passes per hour for whole of night recording). These figures are considerably lower than figures presented by Brown *et al.* (1997) and Law *et al.* (1998) because they provide data from surveys conducted during the first hour post-sunset, a time of peak micro-bat activity. It is possible that low rates of activity may have been recorded in the Conondale Ranges because the tape recorder failed to switch on in time to record any calls.
2. the number of species recorded was less than half that recorded from the forests of the Conondale Ranges using all recording means (hand-held Anabat recorders and trapping).

There is likely to be a number of reasons why so few species were detected and why it was difficult to identify these to species. Part of the explanation may be due to the habitat preferences of species (i.e., certain species were not recorded because detectors were not placed in preferred habitat types). Otherwise use of voice activated equipment meant recordings were of poor quality, which led to difficulties in discriminating among species with similar calls. The quality of a bat call depends on call length, completeness of the sequence, orientation of the detector in relation to the bat, and the level of background noise. High quality calls are those which contain enough information to identify the species producing them. The amount of information required varies among species, but in general, good calls are longer and less cluttered by echoes and background noise than poor quality calls. In this study the proportion of poor calls was high due to the following :

1. Calls were shortened (i.e., the early parts of calls were lost). The voice activation tape recorders often missed the first part of each call, because of the time it took for the tape recorder's motor to start running. As a result, the calls were brief, with only few pulses per sequence (or call). For ultrasound identification, an ideal call should last longer than one second. In this study, most recordings lasted only milliseconds. This is most likely to have resulted from the fact that (i) bats flew quickly past the stationary microphone, particularly the rapid flying, highly manoeuvrable bats such as *M. australis*, which are difficult to record with a stationary microphone that cannot be oriented toward the source of the signal to record the entire call; or (ii) bats were too far away to provide a signal of sufficient strength and duration to keep the voice activated recorder in record mode (e.g., fast aerial feeders, foraging high in the canopy). All detection equipment was placed on the ground and facing in an unobstructed direction. The height of the forest canopy ranged from 15 m at the regrowth site to 30 m at the intermediate and unlogged sites. Some species flying at these heights would be beyond the range of the detectors. Elevating the height of the microphone may help to improve the detection range of the detectors.
2. Recordings were swamped by background noise (i.e., there was a high noise to signal ratio) or distorted. There can be a high degree of attenuation of signals through air if insect noise or environmental conditions are not conducive to transmission (e.g.,

high wind in the canopy). Doppler shift will further lead to distortion of calls. Because the Anabat II detector could not be constantly adjusted toward a bat as it flew over (i.e., the usual procedure when sampling with a hand-held unit), the shift in the call enhanced distortions, which altered the frequency-time graph produced by the Anabat system. This leads to difficulties in identification, particularly when species emit similar frequencies. Additionally, insect noise can be so loud that it will activate recording equipment, leading to wasted space on the tape, lengthened processing time and too little recording space left on the tapes.

Species identification — problems

Environmental conditions, behaviour of bats and inadequacies in sampling techniques reduce the quality of recordings and makes the identification of species with similar calls more difficult, as the following examples indicate.

At each site, a number of calls showed a frequency similar to *Miniopterus australis*, but unfortunately these also contained a high noise to signal ratio. The ultrasound of this species can be confused with *Vespadelus pumilus* because of their similar frequency ranges. There were 46 calls within this frequency range, 23 of them were identified as *V. pumilus*, but the other 23 could have been either species.

The calls of the unknown species (40/50, Table 2) were within the range of *Miniopterus schreibersii*, but could not be identified due to their poor quality. The only other species in southern Queensland known to call within this range, but at the higher end of the frequency range is *Vespadelus troughtoni* (Schulz and de Oliveira 1996). However, it is not known in the Conondale Ranges. *M. schreibersii*, on the other hand, has been previously recorded several times in the region (DNR ultrasound database and trapping records).

Problems also occurred with calls recorded around the 30 KHz frequency; both species of Freetail Bats (*Mormopterus* spp.) recorded by Kehl and Corben (unpubl. report) as well as *Chalinolobus gouldii* employ this frequency. Twenty-five calls within this frequency range were recorded, but eleven of these were of poor quality and could have been either species. *C. gouldii* has been recorded many times in the Conondale Ranges and was expected during this study. However, only one call was confidently attributed to this species. This group of 30 KHz unidentified calls were recorded in both aged classes

Unlogged site. Bundaroo Logging Area (L.A.) now part of Conondale National Park. Photo: Luke Hogan.

Intermediate site. Last logged 1961. South Summer Logging Area (L.A.) Kenilworth State Forest. Photo: Luke Hogan.

Regrowth site. Last logged 1987. Peters Logging Area (L.A.) Kenilworth State Forest. Photo: Luke Hogan 1998.

of logged forests. Even though *C. gouldii* emits low frequency calls, which can increase detection range, its speed and foraging behaviour (Kutt 1995) may have influenced the lack of records of its calls, or possibly the poor quality signals recorded.

The converse of failing to distinguish between species (and thus recording neither) is the problem of overestimation of those species whose signals are so distinctive as to overcome poor quality recordings. *R. megaphyllus* and the two species of Freetail bats (*N. australis* and *Mormopterus* sp.) emit long pulses of low and constant frequency (10 and 30 Khz), which suffer less atmospheric attenuation. For *R. megaphyllus*, its characteristic flight is close to the ground, and thus close to the sampling equipment; therefore these bats may be overestimated relative to other species (Table 2). Indeed, *R. megaphyllus* was the most commonly recorded bat in the intermediate and unlogged sites, while *Mormopterus* sp. was the most frequently recorded bat in the regrowth site. In contrast, *N. australis* was not commonly recorded, which suggests that it may only occur in low numbers in the Conondale Ranges.

Bat diversity and activity — treatment effects

Comparison of the structural vegetation measurements indicated that the intermediate and the unlogged sites were more structurally diverse than the regrowth site (i.e., they were taller, had more layers, more species, and a greater diversity of tree size classes). There was little difference between structural measurements in the intermediate and the unlogged sites, although the intermediate site did display greater diversity in its ground layer.

Species richness of micro-bats was highest in the intermediate site and lowest in the regrowth site. The intermediate site contained three species that the unlogged site did not contain. These were *C. gouldii*, the *Scotorepens* sp. and the unidentified species (40/50). Kutt (1995) referred to *C. gouldii* as a medium to fast aerial feeder foraging close to and above the canopy, or in gaps beside the canopy, with low maneuverability and *Scotorepens orion* as a medium to slow aerial feeding species, foraging below, inside and beside the canopy and sub-canopy, with medium to low maneuverability.

The regrowth site contained fewest species, and these tended to be fast aerial feeders with low maneuverability, foraging above the canopy or in large gaps beside the canopy, such as *Mormopterus* sp., *Mormopterus* sp./*C. gouldii* type, *N. australis* and possibly *M. australis* (Kutt 1995). *Mormopterus* sp. was the most commonly recorded bat in this site.

Rhinolophus megaphyllus was rarely recorded in the regrowth site. It was most common within the intermediate and unlogged sites. This species evidently rarely feeds in thick regrowth, utilizing forest gaps (C. Pavey and L. Hall, pers. comm.).

Bat activity (measured as passes) cannot be measured absolutely via remote detection, because of the potential multiple scoring of individual bats; which can be more problematic than if employing hand-held detection. Fortunately, remote detection using delay switches may provide a more precise activity measure, or at least equivalent to the hand-held measure, because of the time readings provided after each recorded bat pass. Nevertheless, the number of bat passes was highest in the intermediate logged site and lowest in the regrowth. Similar results were obtained by Brown *et al.* (1997) who found that activity levels increased with increasing time since logging, and therefore increasing complexity of forest structure, but showed that an intermediate site had more activity than an older site.

On a qualitative basis, a direct positive relationship is tentatively suggested between structural complexity of the vegetation and bat diversity and activity. Stand age and its structural complexity may contribute to bat diversity and abundance (or activity level) in at least two ways. Firstly, the greater abundance and diversity in the older aged stands compared to the regrowth site could relate to the availability of roosts, which would permit more on-site residents. However, micro-bats are also well known for covering considerable distances in one night to get from their roosts to foraging grounds (e.g., Lunney *et al.* 1988). Secondly, where there is greater structural complexity of vegetation, there should be more foraging niches and species of bat. The latter proposition embraces the "niche theory" of bio-diversity (after Krebs 1972).

Hand-held versus remote monitoring — a conclusion

In general, ultrasonic calls of better quality are detected by hand-held detectors. The detector can be oriented towards a bat as it flies over and can be followed as it flies away from the recorder. This usually reduces effects due to insect noise, signal attenuation and problems with recording only small segment of calls. Fine adjustments can also be made on detectors *in situ* (e.g., by using a higher sensitivity setting). However,

hand-held detectors require an enormous use of operator-effort (which increases research costs), and may lead to biases depending on the degree of operator experience (e.g., some people might be quicker to trigger the recorder).

We are of the opinion that remote sampling methods require more research and testing. The system described in this study would only be of value if used in association with other sampling techniques during surveys or ecological comparisons. Remote detection methods still remain attractive because of their value in providing standardized methods for monitoring bats, without operator-effort constraints or costs. In particular, if delay switches are employed, larger sample sizes can be obtained to increase the power of statistical analyses, time readings after each bat pass can be obtained to help minimize multiple scoring of individual bats and to assist with analysis of bat activity patterns throughout the night (dusk, midnight, dawn).

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REFERENCES

Anon., 1982. *National Forest Policy Statement — A New Focus for Australia's Forests.* Australian Government Publishing Service: Canberra. 51 Pp.

Brown, G. W., Nelson, J. L. and Cherry, K. A., 1997. The influence of habitat structure on insectivorous bat activity in montane ash forests of the Central Highlands, Victoria. *Aust. For.* **60:** 138–46.

Corben, C., 1989. Computer-based call analysis for micro-bat identification. *Macroderma* **5:** 7.

de Oliveira, M. C. and Pavey, C. R., 1995. In search of *Hipposideros semoni* at St. Mary's State Forest, South-east Queensland. *Aust. Bat Soc. Newsl.* **4:** 46–48.

de Oliveira, M. C., 1998. Towards standardised descriptions of the echolocation calls of micro-chiropteran bats: pulse design terminology for seventeen species from Queensland. *Aust. Zool.* **31:** 55–61.

Kehl, J. C. and Corben, C., 1991. *The fauna of the closed forests of the Conondale Ranges, with particular reference to conservation and future land use.* Unpubl. report to the Queensland Forest Service, Queensland Department of Primary Industries.

Krebs, C., 1972. *The experimental analysis of distribution and abundance.* Harper and Row: New York, USA.

Kutt, A. S., 1995. Activity and stratification of micro-chiropteran bat communities in thinned, unthinned and old lowland re-growth forest, east Gippsland. *Vic. Nat.* **112:** 86–92.

Law, B. S., 1996. The ecology of bats in south-east Australian forests and potential impacts of forestry practices: a review. *Pac. Cons. Biol.* **2:** 363–74.

Law, B. S., Anderson, J. and Chidel, M., 1998. A bat survey in state forests on the south-west slopes region of New South Wales with suggestions of improvements for future surveys. *Aust. Zool.* **30:** 467–79.

Lunney, D., Barker, J., Priddel, P. and O'Connell, M., 1988. Roost selection by Gould's Long-eared Bat *Nyctophilus gouldi* Tomes (Chiroptera: Vespertilionidae), in logged forest on the south coast of New South Wales. *Aust. Wildl. Res.* **15:** 375–84.

McDonald, R. C., Isbell, R. F., Speight, J. G., Walker, J. and Hopkins, M. S., 1990. *Australian Soil and Land Survey — Field Handbook.* Second Edition. Inkata Press: Melbourne.

Rhodes, M. P., 1996. *Use of silvicultural regrowth for foraging by Tasmanian bat species.* Unpubl. report to Forestry Tasmania and DPIE, Canberra.

Schulz, M. and de Oliveira, M. C., 1996. Microchiropteran fauna of Kroombit Tops, central Queensland, including a discussion on survey techniques. *Aust. Zool.* **30:** 71–77.

Strahan, R. (ed.), 1995. *The Complete Book of Mammals of Australia.* Australian Museum/Reed Books: Chastwood, New South Wales, Australia.

West, S. D., 1992. *Bat activity and logging in forests of the southeastern tablelands.* Unpubl. report to the Forestry Commission of New South Wales, Beecroft.